

CR135171

A Method to Estimate Weight and Dimensions of Aircraft Gas Turbine Engines

Final Report

Volume II: User's Manual

(NASA-CR-135171) A METHOD TO ESTIMATE
WEIGHT AND DIMENSIONS OF AIRCRAFT GAS
TURBINE ENGINES. VOLUME 2: USER'S MANUAL
Final Report (Boeing Co., Seattle, Wash.)
42 p HC A03/MF A01

N77-25172

Unclas

CSCL 21E G3/07 30428

May 1977

Boeing Military Airplane Development

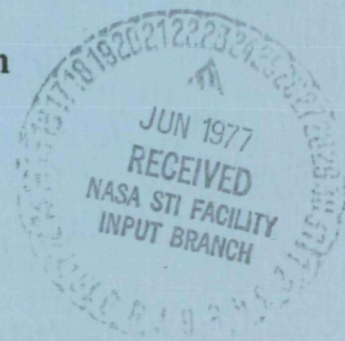
Seattle, Washington 98124

Prepared for

National Aeronautics and Space Administration

NASA-Lewis Research Center

Contract NAS3-19913



1. Report No. CR135171		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle A Method to Estimate Weight and Dimensions of Aircraft Gas Turbine Engines—Final Report Vol II - Users Manual				5. Report Date May 1977	
				6. Performing Organization Code	
7. Authors R. J. Pera, E. Onat, G. W. Klees, E. Tjonneland				8. Performing Organization Report No. D6-44258	
9. Performing Organization Name and Address Boeing Military Airplane Development P. O. Box 3707 Seattle, Washington, 98124				10. Work Unit No.	
				11. Contract or Grant No. NAS3-19913	
12. Sponsoring Agency Name and Address National Aeronautics & Space Administration Washington, D.C. 20546				13. Type of Report and Period Covered Contractor Report	
				14. Sponsoring Agency Code	
15. Supplementary Notes Final Report (see also NASA CR135170 Method of Analysis and CR135172, Programmer's Manual) Program Manager, Laurence Fishbach, Wind Tunnel and Flight Division, Mission Analysis Branch, NASA Lewis Research Center, Cleveland, Ohio					
16. Abstract A computerized method has been developed to estimate weight and envelope dimensions of aircraft gas turbine engines within $\pm 5\%$ to 10%. The method is based on correlations of component weight and design features of 29 data base engines. Rotating components are estimated by a preliminary design procedure where blade geometry, operating conditions, material properties, shaft speed, hub-tip ratio, etc., are the primary independent variables used. The development and justification of the method selected, the various methods of analysis, the use of the program, and a description of the input-output data are discussed in this report.					
17. Key Words (Suggested by Author(s)) Engine Weight Weight Analysis Gas Turbines Turbine Engines Aircraft Propulsion Computerized Simulation Prediction Analysis Techniques				18. Distribution Statement Unclassified-Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified		21. No. of Pages 42	22. Price*	

A METHOD TO ESTIMATE WEIGHT AND DIMENSIONS OF
AIRCRAFT GAS TURBINE ENGINES

Vol. II – Users Manual

By R. J. Pera, E. Onat, G. W. Klees, E. Tjonneland

1.0 INTRODUCTION

This user's manual for the WATE-1 computer program contains a description of input-output data, values of typical inputs and sample cases. A description of the method and engineering analysis is given in CR135170; the Fortran Listings are contained in CR135172.

WATE-1 is designed to function around a component-type engine cycle analysis program NNEP⁽¹⁾. The calculated thermodynamic output data of NNEP is a necessary input to WATE-1 for component sizing. Use of NNEP is not described here since it is unchanged from its normal mode of operation.

Normally, only the design point case of NNEP is used to generate the WATE-1 inputs. Additional NNEP off-design points may be desirable to define other WATE-1 inputs, such as maximum shaft overspeed, or maximum operating temperature for each component. In order to produce the most accurate weight estimate, the design case input data should encompass the maximum performance level required of each component, i.e., maximum flow, work, speed, temperature. All components that contribute weight must also be included in the NNEP engine model. WATE-1 will not calculate weight for components which are not included in the NNEP engine simulation.

WATE-1 has the ability to also accept an input weight scaler for each component so that selected components can be increased or decreased (or eliminated altogether) to determine sensitivities, etc. Both SI and English units of measure can be used.

LIST OF SYMBOLS

R	–	Radius
RPM	–	Speed
TLP	–	$U_t^2/2gJ\Delta h/N_{stage}$
U_t	–	Tip Speed
g	–	32.1415 ft-lbf/sec ² -lb _m
J	–	778 BTU/lb _m
Δh	–	Enthalpy Change
N_{stage}	–	Number of Stages

2.0 PROGRAM STRUCTURE AND DECK STACKING

The overall program structure is shown in the flow chart, Figure 1. NNEP design point data is stored in the "thermodynamic data" for use in calculating weights and dimensions (W/D) in the WATE-1 part of the program. Computer execution time, core storage, and output print requirements have been increased slightly over the NNEP program.

The order of deck stacking of the Job Control cards and NNEP input data are unchanged from the normal operation of NNEP. Two new inputs have been added to the NNEP indicator set. The indicators, IWT = TRUE and IPLT = TRUE signals that the weight and dimensions calculations are to be performed, and the WATE-1 Data Set is required following the NNEP inputs. Figure 2 shows a typical card-stacking arrangement necessary to operate NNEP and WATE-1.

3.0 WATE-1 INPUTS

The WATE-1 inputs are free-field format (NAMELIST), and begin in Column 2. There is no specified order to the inputs; however, for the concurrence in the following discussion, they have been grouped into Plot-Print Indicators, Length Indicators, Mechanical Design Indicators, and Design Values. Figure 3 shows a complete input set for a typical case.

3.1 Plot-Print Indicators

IWT	= TRUE	— do weight calculation	
	FALSE	— do not do weight calculation	must be located in NNEP
IPLT	= T	— gas path layout	Inputs
	F	— no gas path layout	and optional in WATE-1
			Inputs
&W		— placed at end of NNEP inputs to signal beginning of WATE-1 inputs	
ISII	= T	— SI units input	
	F	— English units input	
ISIØ	= T	— SI units output	
	F	— English units	
IØUTCD	= 0	— short form—engine weight, length, and maximum radius	
	1	— long form—component weights and dimensions and short form	
IØUTCD	= 2	— debug option and long and short form	

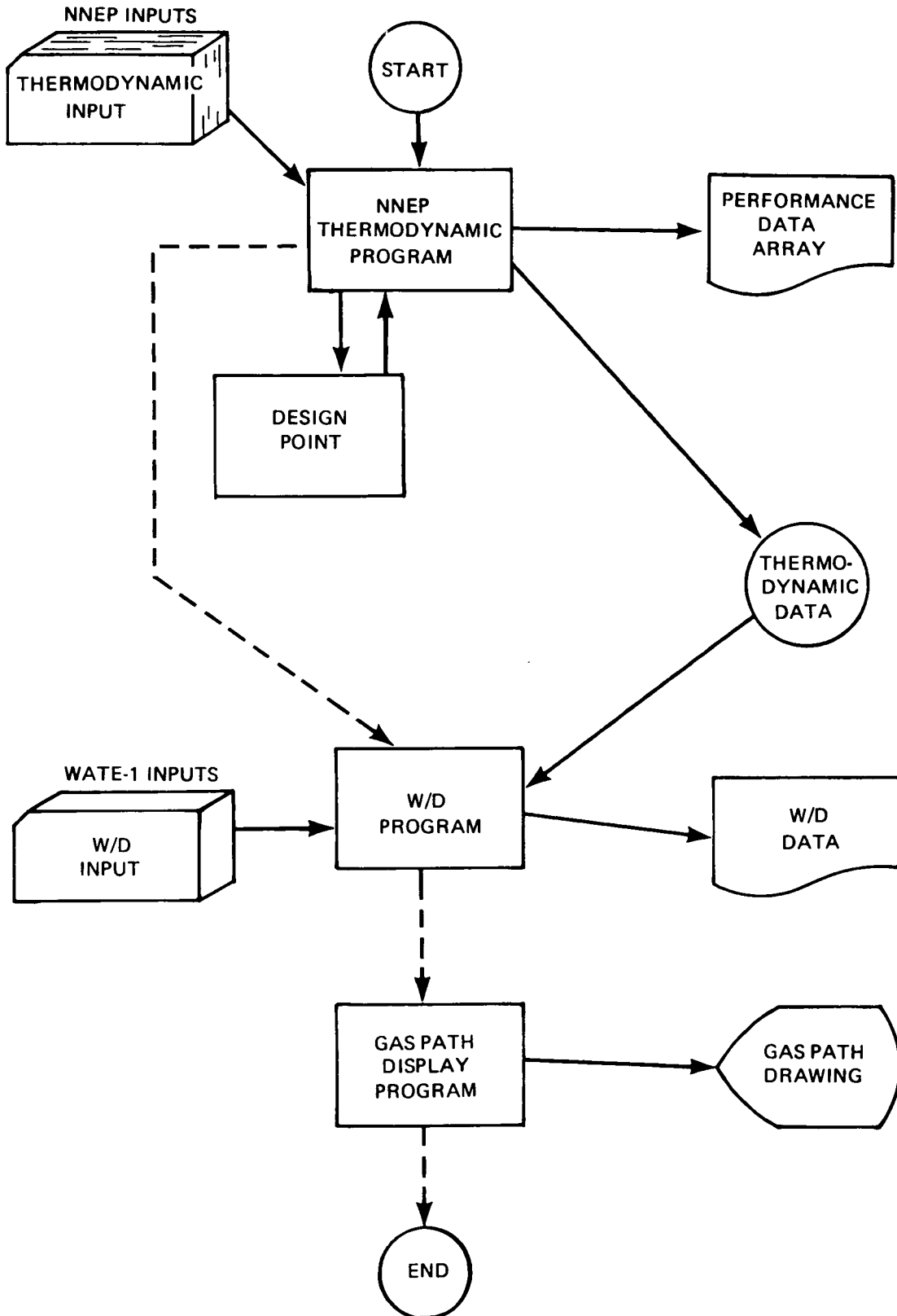


Figure 1 Overall Program Structure

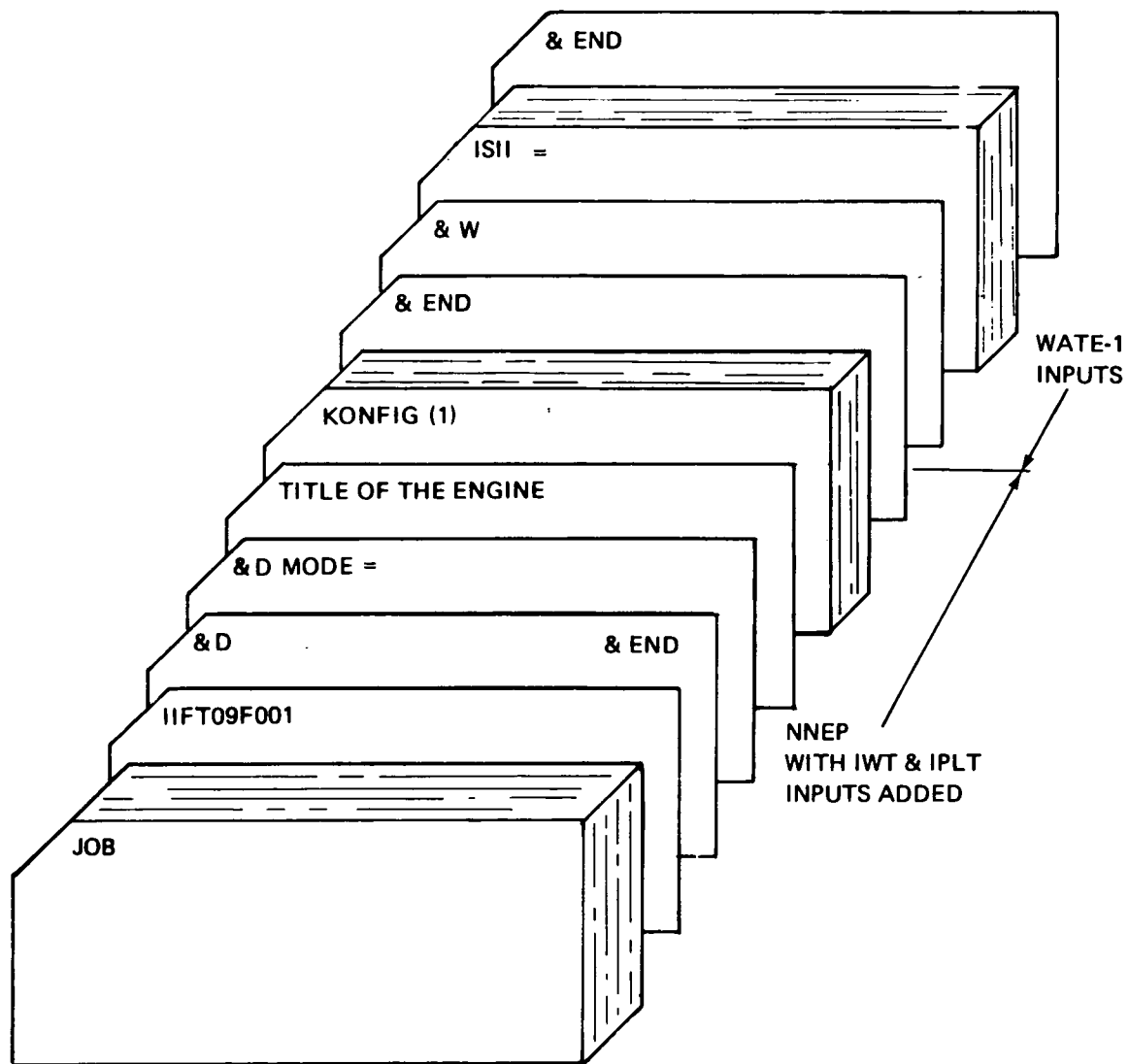


Figure 2 Deck Stacking

```

MODE      1 NOW BEING USED
&W
IPLT=T,
ISII=F,
ISIO=F,
IOUTCD=2,
ILENG(1)=2,3,5,6,7,8,9,10,11,
IWMEC(1,2)='FAN ',1,1,4,3*0,
IWMEC(1,3)='SPLT',6*0,
IWMEC(1,4)='DUCT',0,5*0,
IWMEC(1,5)='LPC ',1,2,4*0,
IWMEC(1,6)='PBUR',1,5*0,
IWMEC(1,7)='HPT ',0,5,-5,3*0,
IWMEC(1,8)='LPT ',1,2,7,3*0,
IWMEC(1,9)='MIX ',0*0,
IWMEC(1,10)='DUCT',2,4*0,
IWMEC(1,11)='NOZ ',1,10,4*0,
IWMEC(1,12)='SHAF',1,8,3*0,2,
IWMEC(1,13)='SHAF',2,7,3*0,5,
DESVAL(1,2)=.524,1.7,.45,1.5,3.5,2.5,.45,0.,0.,1.,0.,2.,1.,
DESVAL(1,3)=15*0.,
DESVAL(1,4)=.45,2*0.,11.,11*0.,
DESVAL(1,5)=.45,1.35,.70,1.2,2.,1.5,.3,0.,0.,1.,0.,2.,1.,
DESVAL(1,6)=100.,.015,
DESVAL(1,7)=.5,.28,1.5,1.5,1.5,.55,150000.,3.,1.,6*0.,
DESVAL(1,8)=.55,.243,1.5,2.,3.,.6,150000.,3.,1.,6*0.,
DESVAL(1,9)=15*0.,
DESVAL(1,10)=.1,2.,
DESVAL(1,11)=1.,14*0.,
DESVAL(1,12)=50000.,.3,.85,12*0.,
DESVAL(1,13)=50000.,.3,13*0.,
&END

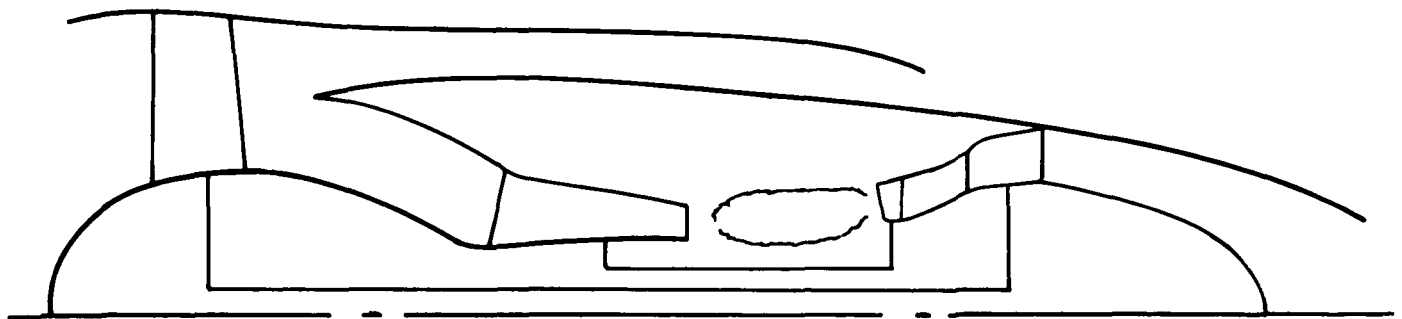
```

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

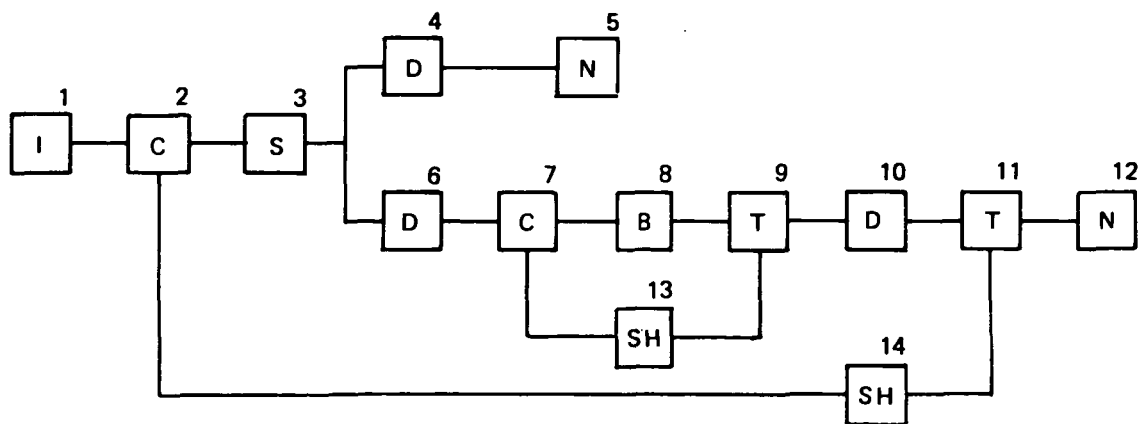
Figure 3 WATE-1 Input

3.2 Length Indicators

The ILENG input specifies only those components that contribute to the total additive engine length. The NNEP component number is specified in ILENG in the order that the components would add in length to achieve the total length. This must start with the first compressor and end with the furthest downstream nozzle. Figure 4 shows a typical engine and the ILENG inputs for that engine. The ILENG input does not include duct (4), nozzle (5) or shafts (13) and (14) because these components do not contribute to the total engine length.



ENGINE LAYOUT



ILENG (1) = 1,2,3,6,7,8,9,10,11,12,

FLOW PATH AND COMPONENT NUMBERS

Figure 4 Length Input

3.3 Mechanical Design Indicators

The mechanical design indicators (IWMEC) must be specified for each component of the NNEP simulation, with the exception of the NNEP Controls, Inlet, and Water Injection or any other component not represented in WATE-1.

A number of shaft components may be required to simulate an engine in NNEP, as shown in Figure 5. WATE-1 will determine the weight only for connecting shafts of major components, such as the typical HP or LP shaft. In the example of Figure 5, only shaft 15 and shaft 17 would be specified. The smaller component number must always be used on the inner shaft, with increasing component numbers as concentric shafts are added around the inner shaft.

IWMEC is a two-dimensional integer array that contains all of the mechanical design indicators. It is of the form IWMEC (N, M), where M is the component number used in NNEP, and N is the variable number as defined below for each component. Each variable in the IWMEC array for each component is identified as shown in Figure 3 in free-field NAMELIST format.

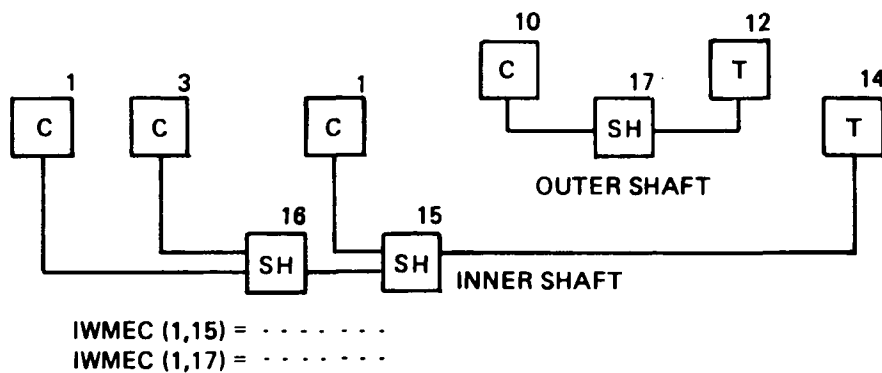


Figure 5 Shaft Input

3.1.1 Compressors

IWMEC Array Location

Description

1	Type of compressor being weighed.
	<ul style="list-style-type: none"> 'FAN' – Typical fan 'FØ' – Outer portion of non-rotating splitter fan 'FI' – Inner portion of non-rotating splitter fan 'RSFØ' – Outer portion of rotating splitter fan 'RSFI' – Inner portion of rotating splitter fan 'LPC' – Low pressure compressor 'HPC' – High pressure compressor
2	This indicates if the fan or compressor has stators.
	<ul style="list-style-type: none"> 1 – Stator weight is calculated 0 – Stator weight is not calculated
3	This is the indicator for 'front' frames in compressors. This input may be:
	<ul style="list-style-type: none"> 0 – No frame 1 – Single bearing frame for turbofans and turbojets without Power Takeoff (PTO) 2 – Single bearing frame with PTO 4 – Two bearing frame, such as the frame in front of the HPC in the JT8D or JT9D which extends outward to the fan outer case and holds two bearings with PTO
4	This is the indicator for the 'rear' frame in a compressor.
	<ul style="list-style-type: none"> 0 – No frame 1 – Single bearing frame for turbofans and turbojet without Power Takeoff (PTO) 2 – Single bearing frame with PTO 4 – Two bearing frame, such as the frame in front of the HPC in the JT8D or JT9D which extends outward to the fan outer case and holds two bearings with PTO
5	This is the component number connecting to this component for split flow compressors only. If this is the Fan Outer, the Fan Inner must be specified. If this is the Rotating Splitter Outer, the inner splitter must be specified, and vice versa.
6	Gear box indicator – 0 – No gear or component number of shaft
7	Number of stages

3.3.2 Turbines

Location	Description
1	This is the type of turbine. 'HPT' – High pressure turbine 'LPT' – Low pressure turbine
2	Indicator for turbine exit frame. 0 – No frame 1 – Frame
3	Compressor number from which the RPM is determined
4	Component number from which the outer radius limit for the turbine is determined. If the component number is positive, the outlet dimension is used. If negative, the inlet dimension is used. If 0, it will use the outlet of the feeding component.
5	Number of stages

3.3.3 Burners

Location	Description
1	This is the type of burner being weighed. The input is the burner name in four spaces. 'PBUR' – Primary burner (airframe will be included) 'DBUR' – Duct burner (a mean radius is specified) 'AUG' – Augmentor (no inner wall)
2	This is the indicator for frame weight, normally only for primary burners. This frame includes a bearing. 0 – No frame 1 – Frame

3.3.4 Ducts

Location	Description
1	Input 'DUCT'
2	Indicator as to type of duct 1 – Dummy – i.e., no weight or length 2 – Length input 3 – Length derived as in a duct connecting a splitter and a mixer

3.3.5 Shafts

Location	Description
1	'SHAF' – Standard shaft
2	Shaft number from inner to outer, i.e., 1, 2, 3, 4 or 5
3-6	Turbine numbers connected to this shaft. The last entry is the furthest downstream turbine. This is used for power summation.
7	First upstream compressor connected to the shaft

3.3.6 Mixers

Location	Description
1	Type of mixer
	'MIX' – The coannular emergence of two streams without mechanical mixer
	'FMIX' – Forced mixer, mechanical, i.e., Daisy lobed mixer
2	Indicator for primary input node
	0 – Primary is inner
	1 – Primary is outer

3.3.7 Nozzles

Location	Description
1	'NOZ' – Input
2	Nozzle type
	1 – Convergent
	2 – C-D variable area

Location	Description
3	Component number from which the nozzle inlet diameter can be determined. If this diameter is taken from the inlet of the component, the (–) component number must be entered. If (+), the exit node will be used. If the previous component determines the diameter, this location may be zero.
4	Thrust reverser type
	0 – None
	1 – Fan
	2 – Primary

3.3.8 Splitters

Location	Description
1	'SPLT' -- Input
2	1 -- If inner stream is not primary

3.3.9 Annulus Inverting Valve

Location	Description
1	Input 'VALV'
2	Location of Valve
	1 -- Inner
	2 -- Outer
3	Component Number of Opposite Duct
4	0 If Fixed, 1 If Movable

3.3.10 Heat Exchangers

Location	Description
1	Input 'HTEX'
2	Type
	1 -- Fixed Tube
	2 -- Rotary
3	Flow Direction
	1 -- Parallel Flow
	2 -- Counter Flow

3.4 Design Values

This section contains the mechanical and aerodynamic design data necessary to determine the weight and dimensions of each component. A summary of this array is shown in Table 1. If desired, the default values, Table 2, can be used for any component by not specifying the inputs for that component. The data required is in the floating-point two-dimensional array DESVAL (N, M), where M is the component number from NNEP and N is as defined below. A typical set of inputs is shown in Figure 3, and a typical range of values is shown in Table 3.

The calculated component weight can be adjusted by an input scaler, DESVAL (15, M), which is a factor applied to the calculated weight. A zero value, however, denotes that no scaling is used. If it is desired to zero-out the weight of a component, the scaler can be set to a trivial quantity such as .0001.

Table 1 DESVAL/DEFAULT Array

POSITION TYPE	1	2	3	4	5	6	7	8
COMP TURB	MNI MNI	PRM TLP *	H/T SOLID	SOLID ARI	ARI ARO	ARO MNO	MNO REFSTR .2% YIELD STRESS FOR DISK	TMAXI MODE
BURN DUCTS	VR MACH	TR L/H	DIA MEAN DIA MEAN	REFLOC REFLOC				
TRAN/ SHAFTS	STRESS L/H	RHO NO. PASS	H/T					
MIXERS	L/H	NO. PASS	MNI	MNØ	RH	WTIC	WTOC	WTW
AIV	#TUBE	MNIP	MNIS	BPR				
HEATEX	L/D							
NOZ	MNI	H/T						
SPLT								

$$*TLP = \frac{\mu_T^2}{2gJ_{\Delta h/N_{STAGES}}}$$

POSITION TYPE	9	10	11	12	13	14	15
COMP TURB	TMAXO RPMR	RPMR	RHO BLADE	MODE	RPMSC	TMET	WEIGHT SCALER
BURN DUCTS							
SHAFTS							
MIXERS							
AIV							
HEATEX							
NOZ							

Table 2 DEFAULT Array

TYPE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FAN	.55	1.7	.45	1.5	4.	3.	.45	0.	0.	1.	2.	1.	0.	0.	0.
LPC	.5	1.5	.4	1.5	4.	3.	.45	0.	0.	1.	0.	2.	1.	0.	0.
HPC	.4	1.4	.7	1.5	3.	1.5	.3	0.	0.	1.0	0.	2.	1.	0.	0.
HPT	.3	.25	1.5	1.5	1.5	.45	125000.	2.	1.	6*0.					
LPT	.45	.25	1.5	2.	4.	.55	125000.	2.	1.	6*0.					
PBUR	100.	.015	13*0.												
DBUR	150.	.015	13*0.												
AUG	300.	.015	13*0.												
DUCT	.4	1.	0.	-1.	11*0.										
SHAFT	50000.	.286	13*0.												
MIXERS	1.	8.	13*0.												
NOZ	1.	14*0.													
AIV	1.	8.	.5	.5	1.1	1.1	1.1								
HTEX	5000.	.5	.5												

Table 3. Typical Range of Input Values for DESVAL/DEFAULT

TYPE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FAN	.5-6	1.5-1.8	.4-5	1.-1.5	3.-5.	2.-3.	.45-.55	0.	0.	1.	0.	*	1.	0.	*
LPC	.45-6	1.5-1.8	.4-5	1.-1.5	3.-5.	2.-3.	.45-.55	0.	0.	1.	0.	*	1.	0.	*
HPC	.4-5	1.4-1.7	.6-8	1.-1.5	2.-5.	1.-2.	.2-3	0.	0.	1.	0.	*	1.	0.	*
HPT	.3-4	.2-3	1.-1.5	1.-2.	1.-2.	.45-.5	100 KSI 150 KSI	*	1.	0.	0.	0.	0.	0.	
LPT	.4-5	.1-3	1.-1.5	2.-3.	4.-6.	.55-.6	100 KSI 150 KSI	*	1.						
PBUR	100-150	.01-.02	*	*											
DBUR	150-200	.01-.02	*	*											
AUG	200-300	.01-.02	0.	*											
DUCB	.4-5	*	*	*											
SHAFT	40-50 KSI	.28-.31	0.-.85												
MIXERS	1.-2.	7.-9.													
NOZ	1.-2.														
AIV	.8-1.2	6.-10.	.4-6	.4-6	*	*									
HTEX	5000.	.3-5	.3-5	*											

*NOT APPLICABLE – SEE TEXT

3.4.1 Compressor

Array Location	Description
1	Compressor face inlet Mach number
2	Maximum first stage pressure ratio
3	Compressor face hub-tip ratio – R_h/R_t
4	Blade solidity, ratio of blade cord to blade spacing
5	Blade aspect ratio at first stage
6	Blade aspect ratio at last stage
7	Compressor exit Mach number
8	Maximum compressor inlet temperature. ZERO If design point temperature is to be used for material selection $^{\circ}R$, $^{\circ}K$.
9	Maximum compressor outlet temperature. ZERO If design point temperature is to be used for material selection $^{\circ}R$, $^{\circ}K$.
10	Maximum speed ratio – RPM_{max}/RPM_{design}
11	Blade material density. ZERO If WATE-1 is to select material. lb/in^3 , Kg/cc compressor design type
12	1. Constant hub radius design 2. Constant mean radius design 3. Constant tip radius design
13	RPM, scaler, normal input is 1. – use to match known RPM of engine
14	Temperature at which a change of material is required. If ZERO 1160 $^{\circ}R$ will be used, $^{\circ}R$, $^{\circ}K$.
15	Compressor weight scaler, input ZERO If no scaling is desired.

3.4.2 Turbines

Location	Description
1	Turbine face inlet Mach number
2	Turbine loading parameter $U_T^2/2gJ h/N_{stages}$
3	Blade solidity blade cord/blade spacing
4	Blade aspect ratio of first stage
5	Blade aspect ratio of last stage
6	Turbine exit Mach number
7	Disk reference stress – .2% yield, this selects disk material. lb/in^2 , $Newton's/cm^2$

8	Turbine design type
	1. Constant tip radius design
	2. Constant mean radius design
	3. Constant hub radius design
9	Maximum speed ratio – RPM_{max}/RPM_{design}
10	Turbine control radius inches/cm – blank if transferred from a component
11	Density of material in turbine blades – $lb/in^3/KgKc$
12-14	
15	Turbine weight scaler, input ZERO.—If no scaling is desired.

3.4.3 Burners

Location	Description
1	Burner through-flow velocity. ft/sec, m/sec.
2	Burner airflow residency time, sec.
3	Burner mean diameter, in. or cm. If zero, diameter is calculated to match connecting component.
4	Component number for calculating mean burner diameter. Enter zero if diameter is specified.
5-14	Not used.
15	Burner weight scaler, enter ZERO.—If no scaling is desired.

3.4.4 Ducts

Location	Description
1	Duct Mach number.
2	Length to height ratio of duct, required if mode 2 is used in IWMEC.
3	Duct mean diameter, in. or cm. If 0., duct diameter is calculated based on node specified below.
4	Node number to calculate mean diameter. Enter 0, if mean diameter is specified. Enter -1, if connecting component is to be used.
5-14	Not used.
15	Weight scaler, ZERO.—if no scaling is desired.

3.4.5 Shafts

Location	Description
1	Shaft allowable stress. lb/in ² , Newton's/cm ²
2	Shaft material density. lb/in ³ , Kg/cc
3	Diameter ratio of shaft $D_{\text{inner}}/D_{\text{outer}}$.
4-14	Not used.
15	Shaft weight scaler. ZERO If no scaling desired.

3.4.6 Mixers

Location	Description
1	Effective length to diameter ratio of mechanical mixer, $L/2A/\pi$, where L is the mixer length inlet to exit, A is the total flow area. Enter 0. if not a mechanical (forced) mixer.
2	Number of passages (or lobes) in mixer.
3-14	Not used.
15	Weight scaler. Enter ZERO. if no scaling is used.

3.4.7 Nozzles

1	Length to diameter ratio of nozzle
2	Bypass ratio for mixed flow nozzle for T/R weight.
3-14	Not used.
15	Weight scaler. ZERO. if no scaling desired.

3.4.8 Splitters

Location	Description
1	Only input if first calculated component in flow path. Mach number in.
2	H/T ratio in.
3-14	Blank.
15	Weight scaler.

3.4.9 Annulus Inverting Valve

Location	Description
1	Specific length – $L/\sqrt{4A}/\pi$
2	Number of passages.
3	Mach number of inner.
4	Mach number of outer.
5	Hub radius in inches/cm or – component number from which hub radius is taken or blank if feeding component determines the hub radius.
6	Inner cylinder weight – $\text{lb/ft}^2/\text{Kg/m}^2$.
7	Outer cylinder weight – $\text{lb/ft}^2/\text{Kg/m}^2$.
8	Wall weight - $\text{lb/ft}^3/\text{Kg/m}^2$.
9-14	Blank.
15	Weight scaler.

3.4.10 Heat Exchangers

Location	Description
1	Number of tubes if “Fixed” type.
2	Mach number in primary stream.
3	Mach number in secondary stream.
4	Engine Bypass ratio if “Rotary” type.

4.0 PROGRAM OUTPUT

The output from WATE-1 may be selected in any of three output formats. Either English or SI units can be selected. Examples of the output for the sample case, Figure 3, are shown for the short output in Figure 6, the long form, Figure 7, and the debug output, Figure 8. This output shows the mechanical design and weight breakdown within the individual component. The units in the output section are shown in Table 4 for English and SI units. The type of units used are noted in the units section of the output.

A flow path layout is also available for conventional type engines. A typical layout is shown in Figure 9. The layout is scaled such that it will fit on one page of the output.

TOTAL BARE ENGINE WEIGHT= 2915. ACCESSORIES= 262.02
 ESTIMATED TOTAL LENGTH= 206. ESTIMATED MAXIMUM RADIUS= 29.

Figure 6 Short Output

WEIGHT INPUT DATA IN ENGL UNITS
 WEIGHT OUTPUT DATA IN ENGL UNITS

COMP NO	WT EST	COMP LEN	ACCU LEN	UPSTREAM RADIUS				DOWNSTREAM RADIUS				NSTAGE
				RI	RO	RI	RO	RI	RO	RI	RO	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0
2	1029.	29.	29.	9.	20.	0.	0.	13.	18.	0.	0.	3
3	0.	0.	29.	0.	0.	0.	0.	13.	16.	16.	18.	0
4	29.	62.	91.	16.	18.	0.	0.	16.	18.	0.	0.	0
5	616.	25.	54.	9.	13.	0.	0.	11.	11.	0.	0.	10
6	250.	18.	72.	9.	13.	0.	0.	9.	13.	0.	0.	0
7	126.	5.	78.	10.	11.	0.	0.	10.	13.	0.	0.	2
8	409.	13.	91.	9.	12.	0.	0.	9.	14.	0.	0.	2
9	0.	0.	91.	4.	16.	16.	21.	4.	21.	0.	0.	0
10	46.	58.	149.	0.	29.	0.	0.	0.	29.	0.	0.	0
11	295.	58.	206.	0.	29.	0.	0.	0.	27.	0.	0.	0
12	40.	0.	0.	9.	20.	10.	11.	0.	0.	0.	0.	0
13	14.	0.	0.	9.	13.	0.	0.	0.	0.	0.	0.	0

TOTAL BARE ENGINE WEIGHT= 2915. ACCESSORIES= 262.02
 ESTIMATED TOTAL LENGTH= 206. ESTIMATED MAXIMUM RADIUS= 29.

Figure 7 Long Output

* *
* FAN 2 *
* *
*****2

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.524	570.	519.	1905.	1579.	6.9517	1.4095

U TIP	STRESS	DEN	W/AREA	TR	H/T
1258.9	26757.6	0.168	2.339	1.800	0.450

COMPRESSOR 2 MECHANICAL DESIGN

LOADING	N STG	DIAM	U TIP C	RPM	C RPM
0.874	3.00	39.98	1258.9	7216.9	7216.9

FRAME WT = 95.67

STAGE 1

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
65.	59.	59.	0.	26.	7.4	0.168	0.168	3.50
PK	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.4789	16.7	0.524	6.952	8.99	19.99	59	1256.9	26758. 209. 519.

STAGE 2

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
91.	34.	34.	51.	21.	6.2	0.168	0.168	3.00
PK	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.4155	16.7	0.499	5.180	11.02	18.95	67	1193.2	20191. 231. 588.

STAGE 3

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
97.	23.	23.	46.	19.	5.7	0.168	0.168	2.50
PK	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.3671	16.7	0.475	4.017	12.17	18.23	70	1148.1	15768. 208. 658.

FRAME WT = 255.15

N STG	WEIGHT	LENGTH
3	1028.68	28.80

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.450	582.	727.	5447.	4743.	3.2206	1.3951

PR	AD EF	PU	TO	HP
2.8600	0.8700	5447.2	726.9	16910.
HI	HO	WI	CWI	
123.95	174.07	238.50	265.00	

***** TOTAL COMP WEIGHT IS 1028.680

Figure 8 Debug Output

```

*****
*           *
*  HPC    5  *
*           *
*****2

```

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.450	582.	727.	5447.	4743.	1.8196	1.3951

U TIP	STRESS	DEN	W/AREA	TR	H/T
1285.1	23331.5	0.168	0.687	1.200	0.700

COMPRESSOR 5 MECHANICAL DESIGN

LOADING	N STG	DIAM	U TIP C	RPM	C RPM
0.651	10.00	25.58	1085.6	11515.5	9727.5

FRAME WT = 118.22

STAGE 1

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
24.	14.	14.	36.	10.	4.5	0.168	0.168	2.00
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.3603	17.8	0.450	1.820	8.95	12.79	50	1285.1	23331. 99. 727.

STAGE 2

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
20.	9.	9.	29.	8.	3.6	0.168	0.168	1.94
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.3241	17.8	0.435	1.442	9.42	12.45	60	1250.7	18516. 75. 800.

STAGE 3

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
16.	6.	6.	25.	7.	3.0	0.168	0.168	1.89
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.2948	17.8	0.420	1.171	9.75	12.19	70	1225.3	15048. 59. 873.

STAGE 4

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
13.	4.	4.	21.	6.	2.6	0.168	0.168	1.83
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.2704	17.8	0.405	0.970	9.98	12.00	81	1206.2	12477. 49. 946.

STAGE 5

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
11.	3.	3.	18.	5.	2.2	0.168	0.168	1.78
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.2499	17.8	0.390	0.818	10.15	11.86	93	1191.5	10527. 41. 1017.

STAGE 6

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
10.	3.	3.	16.	4.	2.0	0.168	0.168	1.72
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.2324	17.8	0.375	0.701	10.28	11.74	104	1180.1	9018. 36. 1089.

Figure 8 Cont.

STAGE 7
 WD WB WS WN WC CL RHOB RHOD AR
 9. 2. 2. 14. 4. 1.8 0.168 0.168 1.67
 PR DEL H MACH AREA R HUB R TIP NB U TIP STR WEIGHT TIN
 1.2173 17.8 0.360 0.608 10.39 11.65 115 1171.0 7829. 32. 1159.

STAGE 8
 WD WB WS WN WC CL RHOB RHOD AR
 10. 3. 3. 13. 3. 1.6 0.286 0.286 1.61
 PR DEL H MACH AREA R HUB R TIP NB U TIP STR WEIGHT TIN
 1.2042 17.8 0.345 0.534 10.47 11.58 126 1163.6 11712. 39. 1229.

STAGE 9
 WD WB WS WN WC CL RHOB RHOD AR
 15. 3. 3. 12. 3. 1.5 0.286 0.286 1.56
 PR DEL H MACH AREA R HUB R TIP NB U TIP STR WEIGHT TIN
 1.1926 17.8 0.330 0.475 10.53 11.52 136 1157.7 10407. 36. 1299.

STAGE 10
 WD WB WS WN WC CL RHOB RHOD AR
 15. 2. 2. 11. 3. 1.4 0.286 0.286 1.50
 PR DEL H MACH AREA R HUB R TIP NB U TIP STR WEIGHT TIN
 1.1824 17.8 0.315 0.426 10.59 11.47 146 1152.8 9343. 33. 1367.

N STG WEIGHT LENGTH
 10 616.43 25.43

DUCT
 M NU VEL T TOT P TOT P STAT AREA GAM
 0.300 544. 1436. 51236. 48231. 0.3874 1.3539

PR AU EF PD TO HP
 9.4060 0.8700 51235.9 1435.6 33965.
 HI HD W1 CW1
 174.07 352.23 134.75 61.97

***** TOTAL COMP WEIGHT IS 616.477

 * *
 * PBUR 6 *
 * *
 *****2

BURNER NUMBER 6
 RIN ROUT LENGTH MACH WSPEC
 8.756 12.909 18.000 0.055 4.596
 CAS WT LIN WT NOZ WT INC WT FRAME WT OT
 24.2 40.4 17.8 16.4 151.3 250.2

Figure 8 Cont.

*
* HPT 7 *
*
*****2

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.500	1186.	2621.	46112.	39327.	0.3977	1.2968

U TIP	STRESS	DEN	W/AREA	TR	H/T
1106.0	9819.5	0.286	0.246	1.000	0.922

TURBINE 7 MECHANICAL DESIGN

H/T	N STG	LOADING	AREA
0.922	2.000	0.280	0.398

UT	RTIP	RHUB	DEL H	RPM	TORQ
1106.0	11.0	10.1	174.5	11515.5	185913.

STAGE 1

DISK	BLADE	VANE	HWD	CASE	AR
0.4	2.3	8.4	21.7	4.0	1.50

PR	DEL H	MACH	AREA	R HUB	R TIP	NB	U TIP	STR	WEIGHT	LENGTH
1.8453	87.3	0.500	0.398	10.14	11.01	180	1106.0	9820.	42.84	2.02

STAGE 2

DISK	BLADE	VANE	HWD	CASE	AR
10.8	0.4	23.7	35.5	6.8	1.50

PR	DEL H	MACH	AREA	R HUB	R TIP	NB	U TIP	STR	WEIGHT	LENGTH
2.0063	87.3	0.525	0.666	10.14	11.55	116	1160.9	16456.	83.19	3.29

N STG	LENGTH	WEIGHT
2	5.31	126.03

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.550	1149.	2028.	12436.	10243.	1.2074	1.3127

PR	TR	AD EF	PD	TU	TC.1
3.7081	1.2928	0.8600	12435.6	2027.7	2027.7

H IN	H OUT	AREA	FLOW	HP
699.28	524.74	5.17	137.56	33969.

***** TOTAL TURB WEIGHT IS 126.028

*
* LPT 8 *
*
*****2

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.550	1149.	2028.	12438.	10245.	1.2072	1.3127

Figure 8 Cont.

U TIP	STRESS	DEN	W/AREA	TR	H/T
727.0	11708.5	0.286	0.777	1.000	0.765

TURBINE 6 MECHANICAL DESIGN

H/T	N STG	LOADING	AREA
0.765	2.000	0.243	1.207

UT	RTIP	RHUB	DEL H	RPM	TORQ
727.0	11.5	8.8	86.9	7216.9	147693.

STAGE 1

DISK	BLADE	VANE	HWD	CASE	AR
5.0	22.4	66.0	38.9	9.9	2.00

PK	DEL H	MACH	AREA	R HUB	R TIP	NB	U TIP	STR	WEIGHT	LENGTH
1.4669	43.4	0.550	1.207	8.83	11.54	80	727.0	11709.	142.18	4.77

STAGE 2

DISK	BLADE	VANE	HWD	CASE	AR
6.9	27.6	81.4	34.0	9.3	3.00

PK	DEL H	MACH	AREA	R HUB	R TIP	NB	U TIP	STR	WEIGHT	LENGTH
1.5156	43.4	0.575	1.652	8.83	12.59	98	780.6	16019.	159.21	4.17

FRAME WT = 167.79

N STG	LENGTH	WEIGHT
2	13.41	469.18

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.600	1154.	1722.	5594.	4436.	2.3313	1.3249

PR	TR	AD EF	PQ	TQ	TD.1
2.2236	1.1779	0.8600	5593.7	1721.5	1721.5

H IN	H OUT	AREA	FLOW	HP
524.77	437.87	16.80	137.56	16912.

***** TOTAL TURB WEIGHT IS 469.184

* AUG 10 *

*****2

BURNER NUMBER 10

RIN	ROUT	LENGTH	MACH	WSPEC
0.0	24.120	48.000	0.143	11.899

CAS WT	LIN WT	NOZ WT	INC WT	WTOT
23.7	120.0	296.1	0.0	439.8

Figure 8 Cont.

```

*****
*                               *
* NOZ  11  *
*                               *
*****2
NUZZLE  11
WEIGHT=  568.95 LENGTH=  48.239 TR WT=  0.0

```

```

*****
*                               *
* DUCT  4  *
*                               *
*****2
DUCT ,  4
RH=  15.78 RT=  17.69 LENG=  62.16
AREA=  1.401 RHO=.168
      CAS WT      INC WT      WTOT
      15.5408      13.8556      29.3964

```

```

*****
*                               *
* SHAF 12  *
*                               *
*****2
SHAFT  12
      DO      DI      LENG      DN      WT
      3.54      3.01      48.74      0.65      40.03

```

```

*****
*                               *
* SHAF 13  *
*                               *
*****2
SHAFT  13
      DO      DI      LENG      DN      WT
      4.35      3.94      18.00      1.27      14.33

```

```

*****
*                               *
* ACCS WT  *
*                               *
*****2
      ACCS WT= 301.414

```

Figure 8 Cont.

WEIGHT INPUT DATA IN ENGL UNITS
WEIGHT OUTPUT DATA IN ENGL UNITS

COMP NO	WT EST	COMP LEN	ACCU LEN	UPSTREAM RADIUS		DOWNSTREAM RADIUS				NSTAGE		
				RI	RO	RI	RO	RI	RO			
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0	
2	1132.	29.	29.	9.	20.	0.	0.	13.	18.	0.	0.	3
3	0.	0.	29.	0.	0.	0.	0.	13.	16.	16.	18.	0
4	32.	62.	91.	16.	18.	0.	0.	16.	18.	0.	0.	0
5	678.	25.	54.	9.	13.	0.	0.	11.	11.	0.	0.	10
6	275.	18.	72.	9.	13.	0.	0.	9.	13.	0.	0.	0
7	139.	5.	78.	10.	11.	0.	0.	10.	13.	0.	0.	2
8	516.	13.	91.	9.	12.	0.	0.	9.	14.	0.	0.	2
9	0.	0.	91.	4.	16.	16.	21.	4.	21.	0.	0.	0
10	484.	48.	139.	0.	24.	0.	0.	0.	24.	0.	0.	0
11	626.	48.	187.	0.	24.	0.	0.	0.	22.	0.	0.	0
12	44.	0.	0.	9.	20.	10.	11.	0.	0.	0.	0.	0
13	16.	0.	0.	9.	13.	0.	0.	0.	0.	0.	0.	0

TOTAL BARE ENGINE WEIGHT= 3941. ACCESSORIES= 301.41

ESTIMATED TOTAL LENGTH= 187. ESTIMATED MAXIMUM RADIUS= 24.

Figure 8. Cont.

UPDATED INPUT DATA TO REFLECT CALCULATED INPUT

COMPONENT

NO.	TYPE	DATINP1	DATINP2	DATINP3	DATINP4	DATINP5	DATINP6	DATINP7	DATINP8	DATINP9
1	INLET	0.238500 03	0.0	0.146960 02	0.0	0.0	0.900000 00	0.0	0.0	0.0
2	COMPRESS	0.180000 01	0.0	0.400000 04	0.376100 04	0.265900 03	0.376200 04	0.101130 01	0.376300 04	0.992220 00
3	SPLITTER	0.770000 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	DUCT B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	COMPRESS	0.130000 01	0.260000-01	0.514550 04	0.370700 04	0.614190 02	0.370800 04	0.909090 00	0.370900 04	0.132460 01
6	DUCT B	0.100000 00	0.0	0.0	0.265000 04	0.940000 00	0.183000 05	0.0	0.0	0.0
7	TURBINE	0.400000 01	0.100000 01	0.467330 00	0.380100 04	0.706450 00	0.380200 04	0.967270 00	0.962440 00	0.100000 01
8	TURBINE	0.250000 01	0.0	0.385770 00	0.380300 04	0.726330 00	0.380400 04	0.940120 00	0.815580 00	0.100000 01
9	MIXER	0.707730 03	0.639250 03	0.240000 00	0.0	0.0	0.0	0.0	0.0	0.0
10	DUCT B	0.600000-01	0.0	0.0	0.0	0.900000 00	0.183000 05	0.0	0.0	0.0
11	NOZZLE	0.472880 03	0.100000 01	0.0	0.0	0.980000 00	0.100000 01	0.0	0.0	0.100000 01
12	SHAFT	0.400000 04	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01
13	SHAFT	0.600000 04	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01

CASE IDENTIFICATION SIMPLE MODEL

STATION PROPERTY OUTPUT DATA

FLOW STATION	WEIGHT FLOW	TOTAL PRESSURE	TOTAL TEMPERATURE	FUEL/AIR RATIO	REFERRED FLOW	MACH NUMBER	STATIC PRESSURE	INTERFACE FLOW ERROR	CORRECTED
	STATP1	STATP2	STATP3	STATP4	STATP5	STATP6	STATP7	STATP8	
1	0.238500 03	0.146960 02	0.518670 03	0.0	0.238500 03	0.0	0.0	0.0	0.0
2	0.238500 03	0.132260 02	0.518670 03	0.0	0.264990 03	0.0	0.0	0.0	0.0
4	0.238500 03	0.376100 02	0.726870 03	0.0	0.109690 03	0.0	0.0	0.0	0.0
5	0.134750 03	0.376260 02	0.726870 03	0.0	0.619700 02	0.0	0.0	0.0	0.0
6	0.131240 03	0.355810 03	0.143560 04	0.0	0.901830 01	0.0	0.0	0.0	0.0
7	0.350340 01	0.355310 03	0.143560 04	0.0	0.0	0.0	0.0	0.0	0.0
8	0.134050 03	0.320220 03	0.265000 04	0.214250-01	0.139060 02	0.0	0.0	0.0	0.0
9	0.137560 03	0.863760 02	0.202760 04	0.208680-01	0.462760 02	0.0	0.0	0.0	0.0
10	0.137560 03	0.308490 02	0.172160 04	0.208680-01	0.948010 02	0.240000 00	0.374010 02	0.0	0.0
11	0.103750 03	0.376280 02	0.726870 03	0.0	0.477170 02	0.0	0.0	0.0	0.0
12	0.241310 03	0.374010 02	0.131570 04	0.117900-01	0.151010 03	0.0	0.0	0.0	0.0
13	0.241310 03	0.351570 02	0.131570 04	0.117900-01	0.160650 03	0.100000 01	0.187800 02	0.0	0.0
14	0.241310 03	0.351570 02	0.131570 04	0.117900-01	0.160650 03	0.117290 01	0.146960 02	0.0	0.0
15	0.103750 03	0.376280 02	0.726870 03	0.0	0.477170 02	0.127340 00	0.374010 02	0.0	0.0

COMPONENT OUTPUT DATA

COMPONENT NO.	TYPE	DATOUT1	DATOUT2	DATOUT3	DATOUT4	DATOUT5	DATOUT6	DATOUT7	DATOUT8	DATOUT9
1	INLET	0.0	0.0	0.0	0.100000 01	0.100000 01	0.0	0.900000 00	0.100000 01	0.0
2	COMPRESS	0.169120 05	0.400000 04	0.0	0.180000 01	0.400000 04	0.100000 01	0.265900 03	0.870000 00	0.286000 01
3	SPLITTER	0.770000 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	DUCT B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	COMPRESS	0.339690 05	0.600000 04	0.0	0.130000 01	0.514550 04	0.985000 00	0.614180 02	0.870000 00	0.940600 01
6	DUCT B	0.0	0.100000 00	0.0	0.214250-01	0.0	0.101230 05	0.0	0.940000 00	0.265000 04
7	TURBINE	0.339690 05	0.600000 04	0.100000 01	0.400000 01	0.467330 00	0.568000 04	0.706450 00	0.860000 00	0.370730 01
8	TURBINE	0.169120 05	0.400000 04	0.100000 01	0.250000 01	0.385770 00	0.524400 04	0.726330 00	0.860000 00	0.222340 01
9	MIXER	0.707730 03	0.639250 03	0.240000 00	0.101140 01	0.472740 03	0.167730 03	0.0	0.949900-16	0.100000 01
10	DUCT B	0.0	0.600000-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	NOZZLE	0.137850 05	0.133790 04	0.239230 01	0.483930 03	0.472880 03	0.100000 01	0.980000 00	0.187210 01	0.239230 01
12	SHAFT	0.0	0.400000 04	0.400000 04	0.400000 04	0.0	0.0	0.0	0.0	0.0
13	SHAFT	0.0	0.600000 04	0.600000 04	0.600000 04	0.0	0.0	0.0	0.0	0.0

MACH= 0.0 ALTITUDE= 0.0 RECOVERY= 0.9000 0 ITERATIONS 2 PASSED

AIRFLOW (LB/SEC)	238.50	GROSS THRUST	13785.01	FUEL FLOW (LB/HK)	10122.81
NET THRUST	13785.01	TSFC	0.7343	NET THRUST/AIRFLOW	57.9988
TOTAL INLET DRAG	0.0	TOTAL BRAKE SHAFT HP	0.0	BOAT TAIL DRAG	0.0
INSTALLED THRUST	13785.01	INSTALLED TSFC	0.7343	SPILLAGE + LIP DRAG	0.0

Figure 8 Cont.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS FORN

Table 4. Output Units

VARIABLE	SI UNITS	ENGLISH UNITS
Velocity	m/sec	ft/sec
Temperature	$^{\circ}\text{K}$	$^{\circ}\text{R}$
Pressure	n/m^2	lb/ft^2
Area	M^2	ft^2
Stress	N/cm^2	lb/in^2
Density	kg/cm^3	lb/in^3
Weight	kg	lb
Length	cm	in
Enthalpy	kwatts	btu/sec
Horsepower	kwatts	hp
Weight flow	kg/sec	lb/sec
Weight flow/unit area	$\text{kg/m}^2\text{sec}$	$\text{lb/ft}^2 \text{ sec}$
Radius	cm	in

5.0 EXAMPLE CASE

A simple mixed flow augmented turbofan is used as an example for the WATE-1 input and execution. Figure 10 shows a schematic and a block diagram of the engine. From this block diagram, the component numbers are determined.

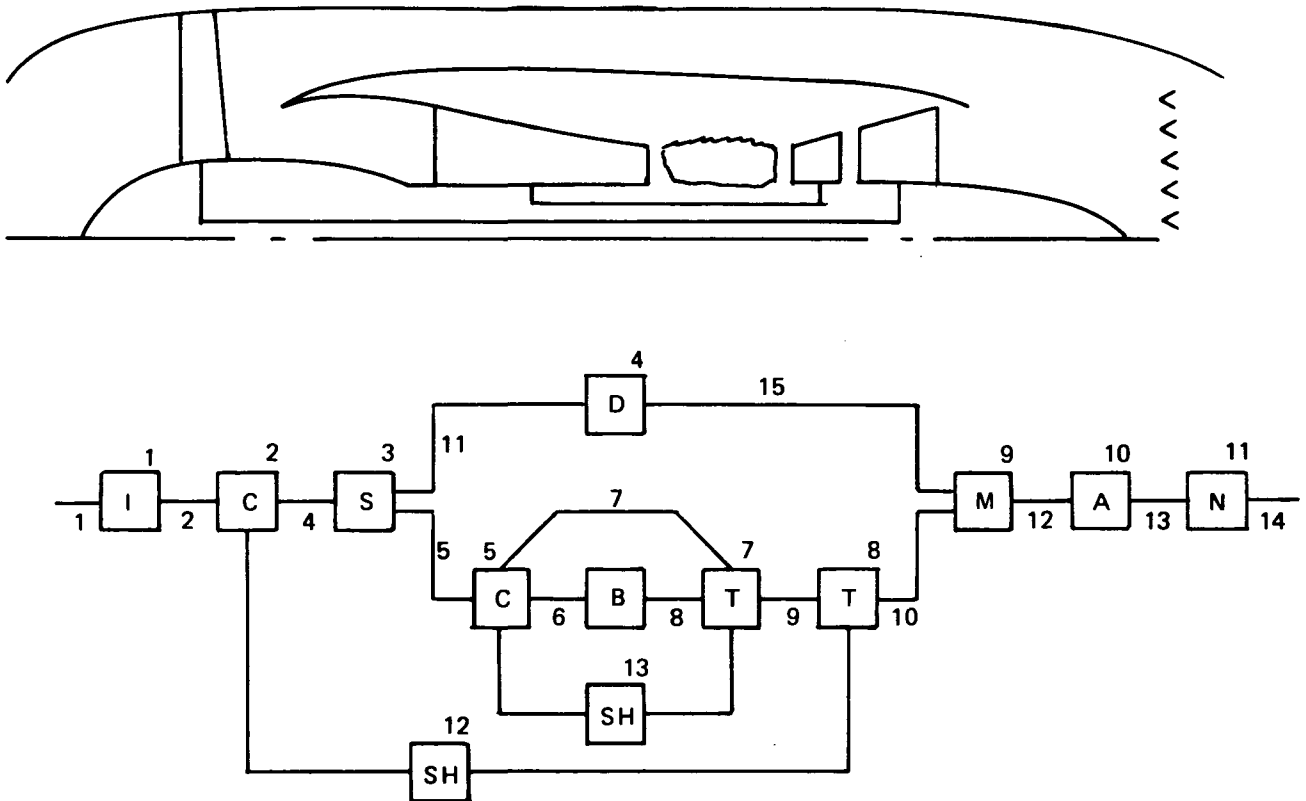


Figure 10 Engine Schematic

To construct the input deck the indicator section must first be set, Figure 11. In this example, the units in and out are English, so ISII and ISIO are set false. Since the weight and gas path layout are desired, IWT and IPLT are set true. The debug option is turned on with IOUTCD set equal to 2. The length inputs are then entered in ILENG. Since the duct (4) and shaft (12) and (13) do not contribute to the total length, they are not entered. Also, the components are entered as the flow would progress through the engine.

```

MODE      1 NOW BEING USED
&#
IPLT=T,
ISII=F,
ISIO=F,
IOUTCD=2,
ILENG(1)=2,3,5,6,7,8,9,10,11,
IWMEC(1,2)='FAN ',1,1,4,3*0,
IWMEC(1,3)='SPLT',6*0,
IWMEC(1,4)='DUCT',3,5*0,
IWMEC(1,5)='HPC ',1,2,4*0,
IWMEC(1,6)='PBUR',1,5*0,
IWMEC(1,7)='HPT ',0,5,-5,3*0,
IWMEC(1,8)='LPT ',1,2,7,3*0,
IWMEC(1,9)='MIX ',6*0,
IWMEC(1,10)='AUG ',6*0,
IWMEC(1,11)='NOZ ',2,-10,4*0,
IWMEC(1,12)='SHAF',1,8,3*0,2,
IWMEC(1,13)='SHAF',2,7,3*0,5,
DESVAL(1,2)=.524,1.7,.45,1.5,3.5,2.5,.45,0.,0.,1.,0.,2.,1.,0,1.1,
DESVAL(1,3)=14*0.,1.1,
DESVAL(1,4)=.45,2*0.,11.,10*0.,1.1,
DESVAL(1,5)=.45,1.35,.70,1.2,2.,1.5,.3,0.,0.,1.,0.,2.,1.,0,1.1,
DESVAL(1,6)=100.,.015,0.,5.,10*0.,1.1,
DESVAL(1,7)=.5,.28,1.5,1.5,1.5,.55,150000.,3.,1.,5*0.,1.1,
DESVAL(1,8)=.55,.243,1.5,2.,3.,.6,150000.,3.,1.,5*0.,1.1,
DESVAL(1,9)=14*0.,1.1,
DESVAL(1,10)=250.,.016,12*0.,1.1,
DESVAL(1,12)=50000.,.3,.85,11*0.,1.1,
DESVAL(1,11)=1.,13*0.,1.1,
DESVAL(1,13)=50000.,.3,12*0.,1.1,
&END

```

Figure 11 WATE-1 Input Example

The IWMEC values are now entered. Since no inlet weight calculations are done, the inlet is not entered. This is true with any component entered in the NNEP KONFIG section; it is not entered in IWMEC if no routine exists to weigh it. In the example, the IWMEC (1,2) card says a “fan” is being weighed. The weight will include stators, IWMEC (2,2) = 1, a front frame, IWMEC (3,2) = 1, and an intermediate frame, IWMEC (4,2) = 4. The IWMEC (1,8) card says a “LPT” is being weighed. It has a turbine exit frame, IWMEC (2,8) = 1, and it is connected to component 2, IWMEC (3,8) = 7. The nozzle has variable area capability, IWMEC (2,11) = 2, and its diameter will be taken from the inlet to the augmentor, IWMEC (3,11) = 10. Since the augmentor has constant diameter, the node position for taking the diameter is of no consequence.

The DESVAL inputs follow the IWMEC inputs. Component numbers used in DESVAL must agree with those used in IWMEC. Input of DESVAL data will override the default values. For the example case, the fan design card DESVAL (1,2) indicates that the compressor inlet Mach number is 0.524, the maximum first stage pressure ratio is 1.7 and the inlet hub/tip ratio is 0.45. The compressor has a blade solidity of 1.5 with a first blade aspect ratio of 3.5. The last stage has an aspect ratio of 2.5 and an exit Mach number of 0.45. The inlet and exit temperatures calculated in NNEP will be used for disk material determination, DESVAL (8,2) and DESVAL (9,2) are 0.; the RPM ratio between maximum and design is 1.0. The blade material will also be chosen by the code because DESVAL (11,2) is 0. The design of the fan is a constant mean line since the mode, DESVAL (12,2), equals 2. Also, no speed scaling or weight scaling will be done since DESVAL (13,2) is 1.0 and DESVAL (15,2) is 0. A material change temperature of 1160°R will be used since DESVAL (14,2) is 0.

The HP turbine DESVAL (1,7) has an inlet Mach number of 0.5 and a turbine loading of 0.28. It has 1.5 solidity with inlet and exit blade aspect ratio equal to 1.5. The exit Mach number is 0.55. The disk material is a high strength super/alloy with a reference stress of 150,000 psi. A constant tip radius is used in the design, DESVAL (8,7) = 3., and a speed ratio of 1. is specified for stress calculations.

To end the inputs, a “&END” is entered. This will initiate execution of WATE-1. The output of WATE-1 is shown in Figure 12 for the example case.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

* *
* FAN 2 *
* *
*****2

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.524	570.	519.	1905.	1579.	6.9517	1.4005

U TIP	STRESS	DEN	W/AREA	TR	H/T
1258.9	26757.6	0.168	2.339	1.800	0.450

COMPRESSOR 2 MECHANICAL DESIGN

LOADING	N STG	DIAM	U TIP C	RPM	C RPM
0.874	3.00	39.98	1258.9	7216.9	7216.9

FRAME WT = 95.67

STAGE 1

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
65.	59.	59.	0.	26.	7.4	0.168	0.168	3.50
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.4789	16.7	0.524	6.952	8.99	19.99	59	1258.9	26758. 209. 519.

STAGE 2

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
91.	34.	34.	51.	21.	6.2	0.168	0.168	3.00
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.4155	16.7	0.499	5.180	11.02	18.95	67	1193.2	20191. 231. 588.

STAGE 3

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
97.	23.	23.	46.	19.	5.7	0.168	0.168	2.50
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.3671	16.7	0.475	4.017	12.17	18.23	70	1148.1	15768. 208. 658.

FRAME WT = 285.15

N STG	WEIGHT	LENGTH
3	1028.68	28.80

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.450	582.	727.	5447.	4743.	3.2206	1.3951

PR	AD EF	PO	TO	HP
2.8600	0.8700	5447.2	726.9	16910.
HI	HO	WI	CWI	
123.95	174.07	238.50	265.00	

***** TOTAL COMP WEIGHT IS 1028.680

Figure 12 WATE-1 Output Example

 * *
 * HPC 5 *
 * *
 *****2

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.450	582.	727.	5447.	4743.	1.8196	1.3951

U TIP	STRESS	DEN	W/AREA	TR	H/T
1285.1	23331.5	0.168	0.687	1.200	0.700

COMPRESSOR 5 MECHANICAL DESIGN

LOADING	N STG	DIAM	U TIP C	RPM	C RPM
0.651	10.00	25.58	1085.6	11515.5	9727.5

FRAME WT = 118.22

STAGE 1

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR	PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT	TIN	
24.	14.	14.	36.	10.	4.5	0.168	0.168	2.00	1.3603	17.8	0.450	1.820	8.95	12.79	50	1285.1	23331.	99.	727.

STAGE 2

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR	PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT	TIN	
20.	9.	9.	29.	8.	3.6	0.168	0.168	1.94	1.3241	17.8	0.435	1.442	9.42	12.45	60	1250.7	18516.	75.	800.

STAGE 3

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR	PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT	TIN	
16.	6.	6.	25.	7.	3.0	0.168	0.168	1.89	1.2948	17.8	0.420	1.171	9.75	12.19	70	1225.3	15048.	59.	873.

STAGE 4

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR	PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT	TIN	
13.	4.	4.	21.	6.	2.6	0.168	0.168	1.83	1.2704	17.8	0.405	0.970	9.98	12.00	81	1206.2	12477.	49.	946.

STAGE 5

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR	PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT	TIN	
11.	3.	3.	18.	5.	2.2	0.168	0.168	1.78	1.2499	17.8	0.390	0.818	10.15	11.86	93	1191.5	10527.	41.	1017.

STAGE 6

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR	PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT	TIN	
10.	3.	3.	16.	4.	2.0	0.168	0.168	1.72	1.2324	17.8	0.375	0.701	10.28	11.74	104	1180.1	9018.	36.	1089.

Figure 12 Cont.

STAGE 7

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
9.	2.	2.	14.	4.	1.8	0.168	0.168	1.67
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.2173	17.8	0.360	0.608	10.39	11.65	115	1171.0	7829. 32. 1159.

STAGE 8

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
16.	3.	3.	13.	3.	1.6	0.286	0.286	1.61
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.2042	17.8	0.345	0.534	10.47	11.58	126	1163.6	11712. 39. 1229.

STAGE 9

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
15.	3.	3.	12.	3.	1.5	0.286	0.286	1.56
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.1926	17.8	0.330	0.475	10.53	11.52	136	1157.7	10407. 36. 1299.

STAGE 10

WD	WB	WS	WN	WC	CL	RHOB	RHOD	AR
15.	2.	2.	11.	3.	1.4	0.286	0.286	1.50
PR	DEL H	MACH	AREA	R HUB	R TIP	NB U TIP	STR	WEIGHT TIN
1.1824	17.8	0.315	0.426	10.59	11.47	146	1152.8	9343. 33. 1367.

N STG WEIGHT LENGTH
10 616.48 25.43

DUCT

M NU	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.300	544.	1436.	51236.	48231.	0.3874	1.3539

PR	AD EF	PO	TO	HP
9.4060	0.8700	51235.9	1435.6	33965.
HI	HO	WI	CWI	
174.07	352.23	134.75	61.97	

***** TOTAL COMP WEIGHT IS 616.477

* *
* PBUR 6 *
* *

*****2

BURNER NUMBER		6				
RIN	ROUT	LENGTH	MACH	WSPEC		
8.758	12.909	18.000	0.055	4.596		
CAS WT	LIN WT	NOZ WT	INC WT	FRAME	WTOT	
24.2	40.4	17.8	16.4	151.3	250.2	

Figure 12 Cont.

```
*****
*
* HPT 7 *
*
*****2
```

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.500	1186.	2621.	46112.	39327.	0.3977	1.2968

U TIP	STRESS	DEN	W/AREA	TR	H/T
1106.0	9819.5	0.286	0.246	1.000	0.922

TURBINE 7 MECHANICAL DESIGN

H/T	N STG	LOADING	AREA
0.922	2.000	0.280	0.398

UT	RTIP	RHUB	DEL H	RPM	TORQ
1106.0	11.0	10.1	174.5	11515.5	185913.

STAGE 1

DISK	BLADE	VANE	HWD	CASE	AR
6.4	2.3	8.4	21.7	4.0	1.50

PR	DEL H	MACH	AREA	R HUB	R TIP	NB	U TIP	STR	WEIGHT	LENGTH
1.8453	87.3	0.500	0.398	10.14	11.01	180	1106.0	9820.	42.84	2.02

STAGE 2

DISK	BLADE	VANE	HWD	CASE	AR
10.8	6.4	23.7	35.5	6.8	1.50

PR	DEL H	MACH	AREA	R HUB	R TIP	NB	U TIP	STR	WEIGHT	LENGTH
2.0063	87.3	0.525	0.666	10.14	11.55	116	1160.9	16456.	83.19	3.29

N STG	LENGTH	WEIGHT
2	5.31	126.03

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.550	1149.	2028.	12436.	10243.	1.2074	1.3127

PR	TR	AD EF	PD	TU	TO.1
3.7081	1.2928	0.8600	12435.6	2027.7	2027.7

H IN	H OUT	AREA	FLOW	HP
699.28	524.74	5.17	137.56	33969.

***** TOTAL TURB WEIGHT IS 126.028

```
*****
*
* LPT 8 *
*
*****2
```

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.550	1149.	2028.	12438.	10245.	1.2072	1.3127

Figure 12 Cont.

U TIP	STRESS	DEN	W/AREA	TR	H/T
727.0	11708.5	0.286	0.777	1.000	0.765

TURBINE 8 MECHANICAL DESIGN

H/T	N STG	LOADING	AREA		
0.765	2.000	0.243	1.207		
UT	RTIP	RHUB	DEL H	RPM	TORQ
727.0	11.5	8.8	86.9	7216.9	147693.

STAGE 1

DISK	BLADE	VANE	HWD	CASE	AR					
5.0	22.4	66.0	38.9	9.9	2.00					
PR	DEL H	MACH	AREA	R HUB	R TIP	NB	U TIP	STR	WEIGHT	LENGTH
1.4669	43.4	0.550	1.207	8.83	11.54	80	727.0	11709.	142.18	4.77

STAGE 2

DISK	BLADE	VANE	HWD	CASE	AR					
6.9	27.6	81.4	34.0	9.3	3.00					
PR	DEL H	MACH	AREA	R HUB	R TIP	NB	U TIP	STR	WEIGHT	LENGTH
1.5156	43.4	0.575	1.652	8.83	12.39	98	780.6	16019.	159.21	4.17

FRAME WT = 167.79

N STG	LENGTH	WEIGHT
2	13.41	469.18

DUCT

M NO	VEL	T TOT	P TOT	P STAT	AREA	GAM
0.600	1154.	1722.	5594.	4436.	2.3313	1.3249

PR	TR	AD EF	PO	TD	TD.1
2.2236	1.1779	0.8600	5593.7	1721.5	1721.5
H IN	H OUT	AREA	FLW	HP	
524.77	437.87	16.80	137.56	16912.	

***** TOTAL TURB WEIGHT IS 469.184

*
* AUG 10 *
*

*****2

BURNER NUMBER 10

RIN	ROUT	LENGTH	MACH	WSPEC
0.0	24.120	48.000	0.143	11.899
CAS WT	LIN WT	NOZ WT	INC WT	WTOT
23.7	120.0	296.1	0.0	439.8

Figure 12 Cont.

```

*****
*
* NOZ 11 *
*
*****2
NOZZLE 11
WEIGHT= 568.95 LENGTH= 48.239 TR WT= 0.0

```

```

*****
*
* DUCT 4 *
*
*****2
DUCT , 4
RH= 15.78 RT= 17.69 LENG= 62.16
AKEA= 1.401 RHO=.168
      CAS WT      INC WT      WTOT
      15.5408      13.8556      29.3964

```

```

*****
*
* SHAF 12 *
*
*****2
SHAFT 12
      DO      DI      LENG      DN      WT
      3.54      3.01      48.74      0.65      40.03

```

```

*****
*
* SHAF 13 *
*
*****2
SHAFT 13
      DO      DI      LENG      DN      WT
      4.35      3.94      18.00      1.27      14.33

```

```

*****
*
* ACCS WT *
*
*****2

ACCS WT= 301.414

```

Figure 12 Cont.

WEIGHT INPUT DATA IN ENGL UNITS
WEIGHT OUTPUT DATA IN ENGL UNITS

COMP NO	WT EST	COMP LEN	ACCU LEN	UPSTREAM RADIUS		RADIUS		DOWNSTREAM RADIUS				NSTAGE
				RI	RO	RI	RO	RI	RO	RI	RO	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0
2	1132.	29.	29.	9.	20.	0.	0.	13.	18.	0.	0.	3
3	0.	0.	29.	0.	0.	0.	0.	13.	16.	16.	18.	0
4	32.	62.	91.	16.	18.	0.	0.	16.	18.	0.	0.	0
5	678.	25.	54.	9.	13.	0.	0.	11.	11.	0.	0.	10
6	275.	18.	72.	9.	13.	0.	0.	9.	13.	0.	0.	0
7	139.	5.	78.	10.	11.	0.	0.	10.	13.	0.	0.	2
8	516.	13.	91.	9.	12.	0.	0.	9.	14.	0.	0.	2
9	0.	0.	91.	4.	16.	16.	21.	4.	21.	0.	0.	0
10	484.	48.	139.	0.	24.	0.	0.	0.	24.	0.	0.	0
11	626.	48.	187.	0.	24.	0.	0.	0.	22.	0.	0.	0
12	44.	0.	0.	9.	20.	10.	11.	0.	0.	0.	0.	0
13	16.	0.	0.	9.	13.	0.	0.	0.	0.	0.	0.	0

TOTAL BARE ENGINE WEIGHT= 3941. ACCESSORIES= 301.41

ESTIMATED TOTAL LENGTH= 187. ESTIMATED MAXIMUM RADIUS= 24.

Fig. 12 Cont.

AAAAA AA A) AAAAAAAAAAAAAA AAAAAAAAAAAAAA NNN

NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN

)

)

)

)

)

1

1

1

;

;

—

-----C/L-----C/L-----C/L-----C/L-----C/L-----C/L-----C/L-----C/L-----) /L-----C/L-----C/L-----C/L-----C/L-----C/L-----C/L-----

Figure 12. Cont.

UPDATED INPUT DATA TO REFLECT CALCULATED INPUT

COMPONENT NO.	TYPE	DATINP1	DATINP2	DATINP3	DATINP4	DATINP5	DATINP6	DATINP7	DATINP8	DATINP9
1	INLET	0.238500 03	0.0	0.146960 02	0.0	0.0	0.900000 00	0.0	0.0	0.0
2	COMPRESS	0.180000 01	0.0	0.400000 04	0.376100 04	0.265900 03	0.376200 04	0.101130 01	0.376300 04	0.992220 00
3	SPLITTER	0.770000 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	DUCT B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	COMPRESS	0.130000 01	0.260000-01	0.514550 04	0.370700 04	0.614180 02	0.370800 04	0.909090 00	0.270900 04	0.132460 01
6	DUCT B	0.100000 00	0.0	0.0	0.265000 04	0.940000 00	0.163000 05	0.0	0.0	0.0
7	TURBINE	0.400000 01	0.100000 01	0.467330 00	0.380100 04	0.706450 00	0.380200 04	0.967270 00	0.902440 00	0.100000 01
8	TURBINE	0.250000 01	0.0	0.385770 00	0.380300 04	0.726330 00	0.380400 04	0.940120 00	0.815580 00	0.100000 01
9	MIXER	0.707730 03	0.639250 03	0.240000 00	0.0	0.0	0.0	0.0	0.0	0.0
10	DUCT B	0.600000-01	0.0	0.0	0.0	0.900000 00	0.183000 05	0.0	0.0	0.0
11	NOZZLE	0.472880 03	0.100000 01	0.0	0.0	0.980000 00	0.100000 01	0.0	0.0	0.100000 01
12	SHAFT	0.400000 04	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01
13	SHAFT	0.600000 04	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01	0.100000 01

CASE IDENTIFICATION SIMPLE MODEL

STATION PROPERTY OUTPUT DATA

FLOW STATION	WEIGHT FLOW STATP1	TOTAL PRESSURE STATP2	TOTAL TEMPERATURE STATP3	FUEL/AIR RATIO STATP4	REFERRED FLOW STATP5	MACH NUMBER STATP6	STATIC PRESSURE STATP7	INTERFACE CORRECTED FLOW ERROR STATP8
1	0.238500 03	0.146960 02	0.518570 03	0.0	0.238500 03	0.0	0.0	0.0
2	0.236500 03	0.132260 02	0.518670 03	0.0	0.264990 03	0.0	0.0	0.0
4	0.236500 03	0.376200 02	0.726870 03	0.0	0.109690 03	0.0	0.0	0.0
5	0.134750 03	0.376200 02	0.726870 03	0.0	0.619700 02	0.0	0.0	0.0
6	0.131140 03	0.355810 03	0.143560 04	0.0	0.901830 01	0.0	0.0	0.0
7	0.350340 01	0.355810 03	0.143560 04	0.0	0.0	0.0	0.0	0.0
8	0.134050 03	0.320220 03	0.265000 04	0.214250-01	0.139060 02	0.0	0.0	0.0
9	0.137560 03	0.863760 02	0.242760 04	0.208680-01	0.462760 02	0.0	0.0	0.0
10	0.137560 03	0.308490 02	0.172160 04	0.208680-01	0.948010 02	0.240000 00	0.374010 02	0.0
11	0.103750 03	0.376200 02	0.726870 03	0.0	0.477170 02	0.0	0.0	0.0
12	0.241310 03	0.374010 02	0.131570 04	0.117900-01	0.151010 03	0.0	0.0	0.0
13	0.241310 03	0.351570 02	0.131570 04	0.117900-01	0.160650 03	0.100000 01	0.187800 02	0.0
14	0.241310 03	0.351570 02	0.131570 04	0.117900-01	0.160650 03	0.117290 01	0.146960 02	0.0
15	0.103750 03	0.376200 02	0.726870 03	0.0	0.477170 02	0.127340 00	0.374010 02	0.0

COMPONENT OUTPUT DATA

COMPONENT NO.	TYPE	DATOUT1	DATOUT2	DATOUT3	DATOUT4	DATOUT5	DATOUT6	DATOUT7	DATOUT8	DATOUT9
1	INLET	0.0	0.0	0.0	0.100000 01	0.100000 01	0.0	0.900000 00	0.100000 01	0.0
2	COMPRESS	0.169120 05	0.400000 04	0.0	0.180000 01	0.400000 04	0.100000 01	0.265900 03	0.870000 00	0.286000 01
3	SPLITTER	0.770000 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	DUCT B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	COMPRESS	0.339690 05	0.600000 04	0.0	0.130000 01	0.514550 04	0.985000 00	0.614180 02	0.870000 00	0.940600 01
6	DUCT B	0.0	0.100000 00	0.0	0.214250-01	0.0	0.101230 05	0.0	0.940000 00	0.265000 04
7	TURBINE	0.339690 05	0.600000 04	0.100000 01	0.400000 01	0.467330 00	0.568000 04	0.706450 00	0.860000 00	0.370730 01
8	TURBINE	0.169120 05	0.400000 04	0.100000 01	0.250000 01	0.385770 00	0.524400 04	0.726330 00	0.860000 00	0.122340 01
9	MIXER	0.707730 03	0.639250 03	0.103870 01	0.101140 01	0.472740 03	0.167730 03	0.0	0.949900-16	0.100000 01
10	DUCT B	0.0	0.600000-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	NOZZLE	0.137850 05	0.183790 04	0.239230 01	0.483930 03	0.472880 03	0.100000 01	0.980000 00	0.187210 01	0.239230 01
12	SHAFT	0.0	0.400000 04	0.400000 04	0.400000 04	0.0	0.0	0.0	0.0	0.0
13	SHAFT	0.0	0.600000 04	0.600000 04	0.600000 04	0.0	0.0	0.0	0.0	0.0

MACH= 0.0 ALTITUDE= 0.0 RECOVERY= 0.4000 5 ITERATIONS 4 PASSED

AIRFLOW (LB/SEC)	138.50	GROSS THRUST	13785.01	FUEL FLOW (LB/HK)	10121.81
NET THRUST	13785.01	TSFC	0.7343	NET THRUST/AIRFLOW	57.7900
TOTAL INLET DRAG	0.0	TOTAL BRAKE SHAFT HP	0.0	BRAKE DRAG	0.0
INSTALLED THRUST	13785.01	INSTALLED TSFC	0.7343	SPILLAGE + LIP DRAG	0.0

Figure 12 Cont.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

6.0 PROGRAM DIAGNOSTICS

The WATE-1 program contains error printout to aid the user in trouble shooting an input deck. A listing of the error messages and their meanings are shown in Table 5. None of these errors will cause termination of the program. The component routine in which the error occurred will be terminated and the program will continue its calculations. The components calculated after an error may or may not be in error.

Table 5. Error Messages

1. "Compressor, I, pressure ratio is too high" - more than 20 compressor stages calculated. First stage maximum pressure ratio too small.
2. "Compressor, I. stage and blade parameters, meaningless" - stage inlet Mach number less than or equal to zero, or hub radius of compressor equals zero.
3. "Duct is not converging - error only called for rotating splitter fan component. Inlet or exit Mach numbers of fan may be input incorrectly.
4. "Error in shaft" - iteration for shaft diameter not converging. Check shaft inputs.
5. "Turbine, I, work or radius too high, RC = , X.XX" - more than 9 turbine stages calculated - turbine loading parameter too small or control radius improperly input.
6. "Turbine, I, stage and blade parameters meaningless" - Mach number or hub radius less than or equal to zero.

REFERENCES

1. Fishbach, L. H. and Caddy, M. J., "NNEP - The Navy-NASA Engine Program," NASA TM X-71857, Dec. 1975.